A quasi-daily pan-Arctic lead product derived from MODIS thermal infrared imagery

Sascha Willmes, Günther Heinemann

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Abstract Polynyas and leads are key elements of the wintertime Arctic sea-ice cover. They play a crucial role in surface heat loss, potential ice formation and consequently in the seasonal sea-ice budget. We apply and evaluate different lead segmentation techniques based on sea-ice surface temperatures as measured by the Moderate Resolution Imaging Spectroradiometer (MODIS). Daily lead composite maps indicate the presence of cloud artifacts that arise from ambiguities in the segmentation process and shortcomings in the MODIS cloud mask. A fuzzy cloud artifact filter is implemented to mitigate these effects and the associated potential misclassification of leads. The filter is adjusted with reference data from thermal infrared image sequences, and applied to daily MODIS data from January to April 2008. The daily lead product can be used to deduct the occurrence, structure and dynamics of wintertime sea-ice leads and to assess seasonal divergence patterns of the Arctic Ocean.

Approach

a) Identify leads by their thermal signature in swath data.

b) Prepare daily binary lead composites, then recognize cloud artifacts using temporal and spatial object properties within a fuzzy filter.

Daily lead composites and fuzzy cloud artifact filtering (FCAF)

- Swath-wise segmentation of leads from MODIS ice-surface temperatures (MOD/MYD29) is applied by using an swath-adaptive threshold on local surface temperature anomalies. Binary images are aggregated into one binary daily composite (Fig1a).
- Three metrics are defined from daily binary lead composites to separate true leads from (cloud) artifacts: two temporal properties (Pixel persistence PP and Object persistence OP) and one spatial property (Object solidity OS), see Fig1b-d.
- A fuzzy rule base is applied to separate true leads from cloud and surface artifacts. Rule weights are used as a tuning parameter, which is adjusted according to manual classification from a set of image sequences.

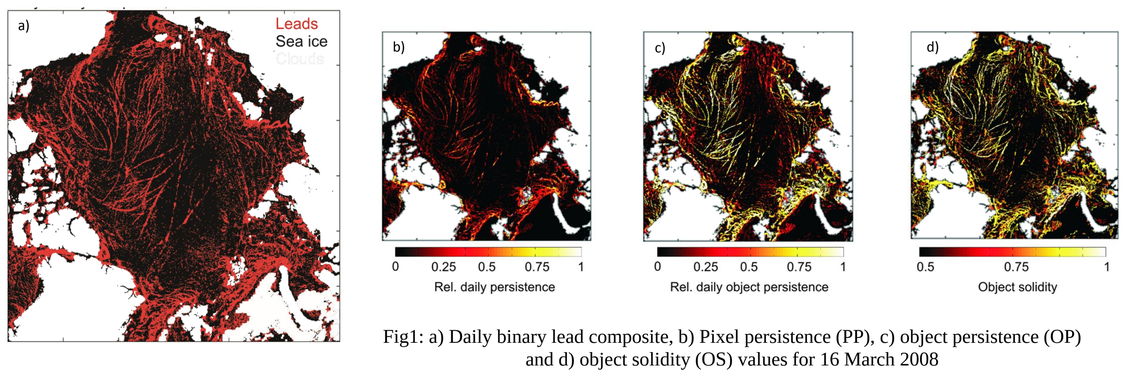

Fig1: a) Daily binary lead composite, b) Pixel persistence (PP), c) object persistence (OP) and d) object solidity (OS) values for 16 March 2008

Filter performance

- Rule weights within the filter process can be chosen to minimize errors in artifact recognition, recognition the combined performance.

Rule weight set	Lead error	Artifact error	Total FCAF error
Min. artifact error	0.71	**0.04**	0.38
Min. lead error	**0.02**	0.82	0.42
Min. total FCAF error	0.05	0.51	**0.28**

- Optimizing the total performance results in a **5% probability of an erroneous lead detection and a 51% probability of an identified artifact being a true lead**, which means a high confidence for identified leads at at the cost of an underestimation of lead frequency (Fig2).

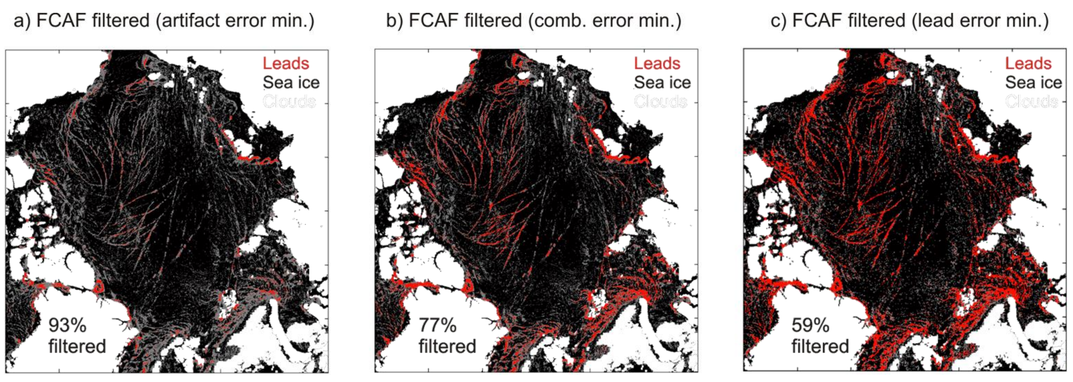

Fig2: FCAF results, weight set applied for a) minimum artifact error, b) minimum total FCAF error, c) minimum lead error, 16 March 2008.

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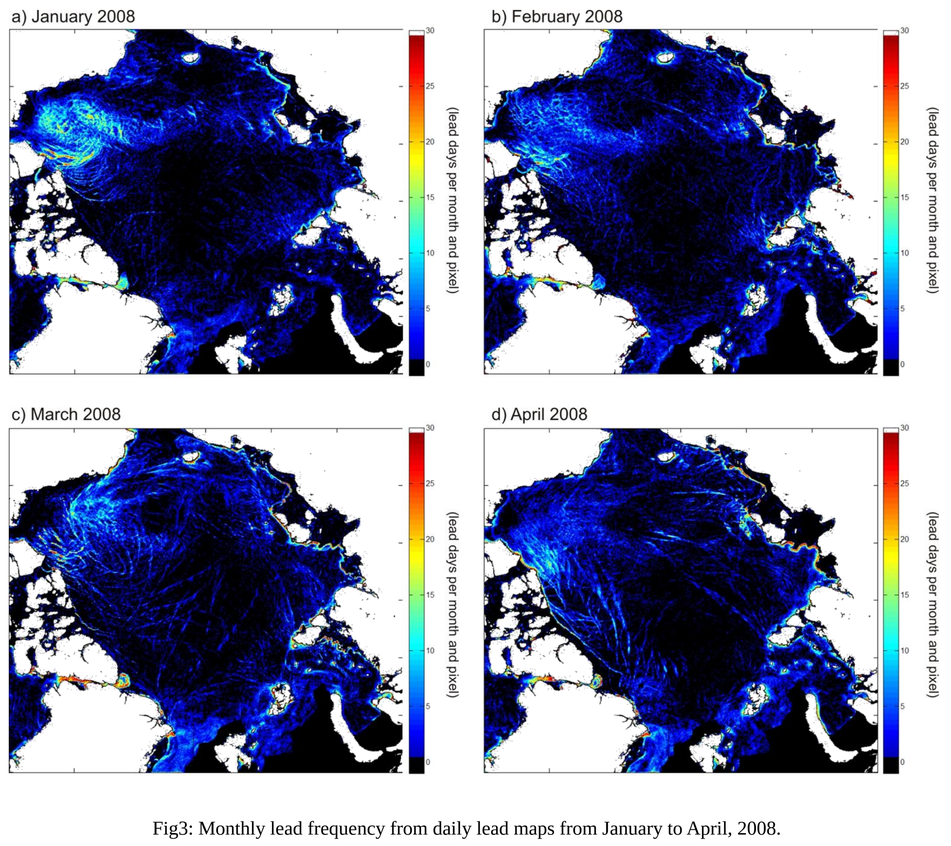
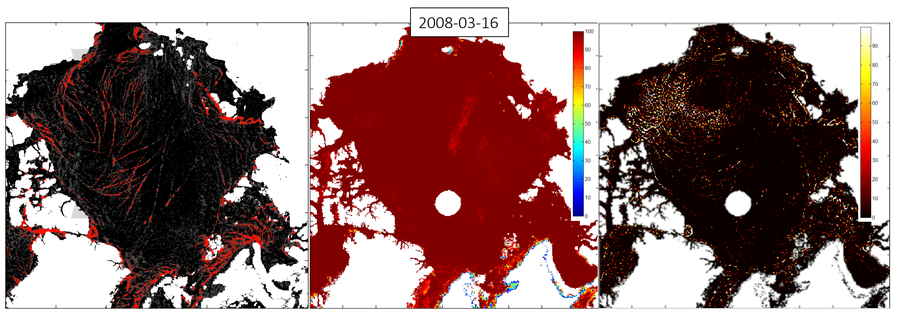


Fig3: Monthly lead frequency from daily lead maps from January to April, 2008.

Comparison with independent daily products



FCAF filtered MODIS lead composite

AMSR-E sea-ice concentration (IUP Bremen); *Spreen et al., 2008*

AMSR-E lead area fraction, *Integrated Climate Data Center ICDC; Röhrs et al., 2012*

Fig4: Comparison of a filtered daily lead map for 16 March 2008 in comparison to ASI sea-ice concentration (Spreen et al., 2008) and a microwave-based lead detection approach (Röhrs et al., 2012).

CONLUSIONS and OUTLOOK

- The quasi-daily lead product can be used to get a pan-Arctic daily overview of the occurrence of sea-ice leads.
- Monthly lead frequencies can provide inter-annual lead climatologies.
- The filter performance will be improved by assimilating independent products.
- It is planned to also include visible MODIS channels into the segmentation process during late spring and early summer to extend the monitoring period.
- The lead identification is dependent on the significance of the local surface-temperature anomaly within one MODIS pixel. The missed fraction of the entire lead width distribution still needs to be determined.

References

Spreen, G., L. Kaleschke, and G. Heygster (2008). Sea ice remote sensing using AMSR-E 89-GHz channels, Journal of Geophysical Research, 113, C02S03, doi:10.1029/2005JC003384.

Röhrs, J., L. Kaleschke, D. Bröhan, and P.K. Siligam PK (2012). An algorithm to detect sea ice leads by using AMSR-E passive microwave imagery. The Cryosphere, 6, 343–352, doi: 10.5194/tc-6-343-2012)

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web link: meteo.uni-trier.de/arcleads.php

contact: willmes@uni-trier.de